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SEAL SYSTEMS IN HYDROSPACE, PHASE II: CYCLIC LOADING OF FLANGE AND HATCH SEAL SYSTEMS

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James F. Jenkins and Fred M. Reinhart

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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93041

13

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ABSTRACT

Long term effects of hydrospace on seals and gaskets are under investigation at NCEL. Phase II includes investigation of the effects of cyclic loading on fifteen seal systems by means of tests in pressure vessels. Fourteen of fifteen test systems withstood 20 pressure cycles to 5,000 psi without leakage or visible seal damage. Long term ocean exposures of seal systems are planned.

INTRODUCTION

Structures which must resist the pressure of the sea water when emplaced on the floor of the deep ocean require seal systems of maximum integrity. Because access for maintenance at great depth is infeasible, such seal systems must, for long periods of time, resist the high pressures, low temperatures and corrosiveness of sea water. To date there has been no long-term testing of seal systems under either actual or simulated deep ocean exposure conditions.

Long-term loading tests of seal systems have been made,[1] and long-term deterioration tests of metals and elastomers in the deep ocean have been made;[2,3,4] however, there is no available data on the combined effects of material deterioration and long-term loading on seal system performance.

In order to determine the combined effects of material deterioration and long-term loading on the performance of seals in the deep ocean, the Naval Civil Engineering Laboratory is engaged in a seal testing and evaluation program. To evaluate seal performance, seal model test jigs were designed and fabricated. Many different types of the basic seal test jigs were constructed to test the performance of several elastomeric seals in flanges and grooves of various configurations. Preliminary tests of these seal model test jigs in pressure vessels showed that they could withstand, without leakage or visible seal extrusion, hydrostatic pressures of 5,000 psi for periods of one and sixteen hours.[5] Similar test jigs were then tested in pressure vessels for their resistance to cyclic loading. The test cycle consisted of sixteen hours of pressurization at 5,000 psi followed by rapid pressure release and eight hours at ambient pressure.

PROCEDURE

The selection and design of the seal systems and seal model test jigs used in this test are given in Reference 5. The jigs were prepared for cyclic loading tests in pressure vessels using the procedure outlined in Reference 5. The model test jig fixture was then loaded and lowered into the pressure vessel. The pressure vessel was then closed and pressurized with chromate inhibited water at the rate of 1,000 psi/min to 5,000 psi and allowed to stand for the prescribed period (16 hours except for longer periods due to weekends and holidays). The pressure was then released at 5,000 psi/minute until ambient pressure was reached. The jigs were left in the pressure vessel below the surface of the chromate inhibited water at ambient pressure for the prescribed period (8 hours) except for longer periods due to equipment

failure, weekends or holidays. Detailed pressure cycling durations and descriptions of test specimens are given in Tables 1 and 2.

After the completion of twenty test cycles the test jigs were removed from the pressure vessel and disassembled for final inspection. The seal systems were considered to have successfully completed the cyclic loading test if no liquid was found in the hollow portion of the test jig during testing or upon final disassembly and if no visible damage of the elastomeric seal was noted upon final inspection.

RESULTS AND DISCUSSIONS

Visual observations of seal model test jigs after disassembly are given in Table 3. The seal test jig with an angular seat, rectangular groove and lip seal tested as a flange seal showed some seal damage after 20 test cycles. The seal, however, remained effective and allowed no leakage. This damaged seal is shown in Figure 1. Damage similar to that noted in this seal system has been reported in similar systems under cyclic loading.[6] The seal test jig with an angular seat, elliptical groove and O-ring seal was found to be completely full of liquid upon final disassembly. The seal was found to be deeply seated in the groove which removed the initial squeeze from the seal at low pressures causing the seal to leak at high pressure. All other seals tested as flange seals were undamaged after 20 test cycles. Light rusting of the flange material of the test jigs in set #1, especially under the seal, did not result in any seal damage or leakage. This small degree of rusting was attributed mainly to the low concentration of sodium chromate inhibitor in the liquid used to pressurize these test jigs. Subsequent tests were conducted using a higher concentration of sodium chromate as a rust inhibitor; no rusting of the flange material was noted.

CONCLUSIONS

Fourteen flange and hatch seal systems evaluated in this phase of testing withstood 20 test cycles of 16 hours at 5,000 psi, 8 hours at 0 psi in sodium chromate inhibited fresh water with no leakage. The seal system using an O-ring in an elliptical groove was found to be completely full of liquid upon final disassembly. This was attributed to the forcing of the ring into the deep groove causing a loss of low pressure seal compression. This loss of seal compression resulted in high pressure seal leakage. Seal damage was noted in some cases in the lip seal system, but did not result in leakage. Light rust found under the seals in one test was attributed to an insufficient concentration of sodium chromate inhibitor but did not lead to any seal leakage.

FUTURE PLANS

Seal test jigs of the types tested will be exposed to the natural ocean environment for extended periods at both deep and shallow water test sites. Test jigs of the same general type but fabricated from materials representative of other alloy types will also be included in natural environment exposures in order to evaluate the effect of corrosion of these materials on their usefulness as a seal flange. Cyclic loading tests of seals as both flange and hatch seal systems will be conducted, if feasible, in natural environments.

REFERENCES

1. Aeronautical Systems Division, Air Force Systems Command Report 56-272 Part VI. "Design Data for O-Rings and Similar Elastic Seals" by George R. Trepus et al, Wright Patterson Air Force Base, Ohio, May 19[illegible].

2. Naval Civil Engineering Laboratory Technical Report R-504: "Corrosion of Materials in Hydrospace" by Fred M. Reinhart, Port Hueneme, California, December 1966.

3. ______________ R-428: "Deep Ocean Biodeterioration of Materials - Part III. Three Years at 5,300 Feet" by J. S. Muraoka, Port Hueneme, California, February 1966.

4. ______________ R-456: "Deep Ocean Biodeterioration of Materials - Part IV. One Year at 6,800 Feet" by J. S. Muraoka, Port Hueneme, California, January 1966.

5. ______________ R-999: "Seal Systems in Hydrospace, Phase I: Mechanical Integrity of Flange Seal Systems" by James F. Jenkins and Fred M. Reinhart, Port Hueneme, California, October 1968.

6. Bowers, J. M., "Test Analysis Report - Skirt Seal Test DSRV-1" Lockheed Missile and Space Corporation, Sunnyvale, California, April 1967.

Table 1. Seal System Configurations.

Jig Set #	Jig	Cover[1]	Base	Seal
1	A	Flat-Rectangular Groove	Flat	O-Ring
1	B	Flat-Rectangular Groove	Flat	Lobed Ring
1	C	Flat-Rectangular Groove	Flat	Lip Seal
1	D	Angular-Rectangular Groove	Angular	O-Ring
1	E	Angular-Rectangular Groove	Angular	Lobed Ring
2	A	Angular-Rectangular Groove	Angular	Lip Seal
2	B	Flat-Dovetail Groove	Flat	O-Ring
2	C	Angular-Dovetail Groove	Angular	O-Ring
2	D	Angular-Elliptical Groove	Angular	O-Ring
2	E	Flat-Rectangular Groove with anti-extrusion device	Flat	Lobed Ring
3	A	Flat-Dovetail Groove	Flat	Lobed Ring
3	B	Angular-Dovetail Groove	Angular	Lobed Ring
3	C	Flat-Rectangular Groove with anti-extrusion device	Flat	O-Ring
3	D	Angular-Rectangular Groove with anti-extrusion device	Angular	O-Ring
3	E	Angular-Rectangular Groove with anti-extrusion device	Angular	Lobed Ring

[1] Detailed descriptions of each cover, base, and seal are given in Reference 5.

Table 2. Cyclic Loading Pressure Durations.

Test Jigs	Cycle #	Hours at 5,000 psi	Hours at 0 psi
Set #1	1	16	8
	2	16	8
	3	16	8
	4	16	96
	5	16	8
	6	16	8
	7	16	8
	8	64	8
	9	16	8
	10	16	8
	11	16	8
	12	16	8
	13	64	8
	14	16	8
	15	16	8
	16	16	8
	17	16	8
	18	64	8
	19	16	8
	20	16	--
Set #2	1	16	8
	2	16	8
	3	64	8
	4	16	8
	5	16	8
	6	16	8
	7	16	8
	8	20	52
	9	16	8
	10	16	8
	11	16	8
	12	16	8
	13	64	8
	14	16	8
	15	16	8
	16	16	8
	17	16	8
	18	64	8
	19	16	8
	20	16	--

Table 2. Cyclic Loading Pressure Durations (cont'd)

Test Jigs	Cycle #	Hours at 5,000 psi	Hours at 0 psi
Set #3	1	16	8
	2	64	8
	3	16	8
	4	16	8
	5	16	8
	6	16	8
	7	64	8
	8	16	8
	9	16	8
	10	16	8
	11	16	8
	12	88	8
	13	16	8
	14	16	8
	15	16	8
	16	64	8
	17	16	8
	18	16	8
	19	16	8
	20	16	--

Table 3. Visual Observations on Seal Model Test Jigs After Cyclic Loading

Jig #*	Visual Observations		
	Jig Bottom	Jig Cover & Groove	Seal
1A	No leakage-very light rust under seal	No rusting	No damage
1B	No leakage-very light rust one area under seal	No rusting	No damage
1C	No leakage-very light rust under seal	Light rust under sealant	No seal damage, seal adhesive extruded both sides of seal
1D	No leakage-light rust away from seal	No rusting	No damage
1E	No leakage-light rust away from seal	No rusting	No damage
2A	No leakage No rusting	No rusting	Lip seal worn, seal adhesive extruded both sides of seal
2B	No leakage No rusting	No rusting	No damage
2C	No leakage No rusting	No rusting	No damage
2D	Full of liquid No rusting	No rusting	No damage
2E	No leakage No rusting	No rusting	No damage

Table 3. Visual Observations on Seal Model Test Jigs After Cyclic Loading (cont'd)

Jig #*	Visual Observations		
	Jig Bottom	Jig Cover & Groove	Seal
3A	No leakage No rusting	No rusting	No damage
3B	No leakage No rusting	No rusting	No damage
3C	No leakage No rusting	No rusting	No damage
3D	No leakage No rusting	No rusting	No damage
3E	No leakage No rusting	No rusting	No damage

*Jig numbers correspond to those in Table 1.

Figure 1. Lip seal damage after 20 cycles. Angular flange seal with rectangular groove.

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